

[COMMUNICATION]

Morphological and Physiological Characterization of the Para-Ocellar Nerve of the Cockroach, *Periplaneta americana*

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ABSTRACT—The structure and physiological properties of the para-ocellar nerve have been examined in American cockroaches. The para-ocellar nerve contains 120–200 fibers, originating from several bundles around the ocellus. The fibers project into the deutocerebrum and descent to terminate in the suboesophageal ganglion. Spike discharges were recorded in the para-ocellar nerve in response to air puffs directed towards the ocellar cornea, indicating that the para-ocellar nerve contains axons of mechanosensory sensilla surrounding the ocellus. It was previously assumed that the para-ocellar nerve coupled ocellar photoreception with neurosecretion of the corpora cardiaca. However, our data could not confirm this assumption, since we could not find responses of the para-ocellar nerve to ocellar illumination.

INTRODUCTION

The dorsal ocellus of insects is usually connected with the protocerebrum by a single ocellar nerve [1]. In cockroaches, however, the ocellus is connected with the brain by two nerves: the ocellar nerve and the para-ocellar nerve. Structure of the ocellus and ocellar nerve has been well documented in cockroaches [1–6], but only little is known about the para-ocellar nerve [7]. Silver impregnation showed two courses of para-ocellar nerve fibers in the deutocerebrum. Some fibers terminated with arborizations in the superior internal cortical area of olfactory lobe, where they keep close proximity to the neurons projecting

their axons into para-cardiac nerve. Other fibers further descend to the circumoesophageal connectives [7]. Based upon this morphology the para-ocellar nerve was assumed to couple ocellar photoreception with the neurosecretion of the corpora cardiaca [7]. However, this assumption has not been examined electrophysiologically or anatomically using electron microscopy.

In the present study, the para-ocellar nerve fibers of American cockroaches *Periplaneta americana* have been examined using cobalt backfills, electron microscopy and electrophysiological techniques.

MATERIALS AND METHODS

Morphology

The para-ocellar nerves of the cockroaches *P. americana* were prepared for scanning and transmission electron microscopy through the same procedures previously reported for the ocellus and ocellar nerve of the same species [4, 5, 8]. The projections of the para-ocellar nerve fibers in the brain were studied by backfilling the fibers from the ocellus with cobalt chloride. Backfilled fibers were examined by light microscopy using the same procedure previously described for the ocellar nerve fibers in the same species [4, 5, 8].

Physiology

The cockroach was fixed on an acrylic platform

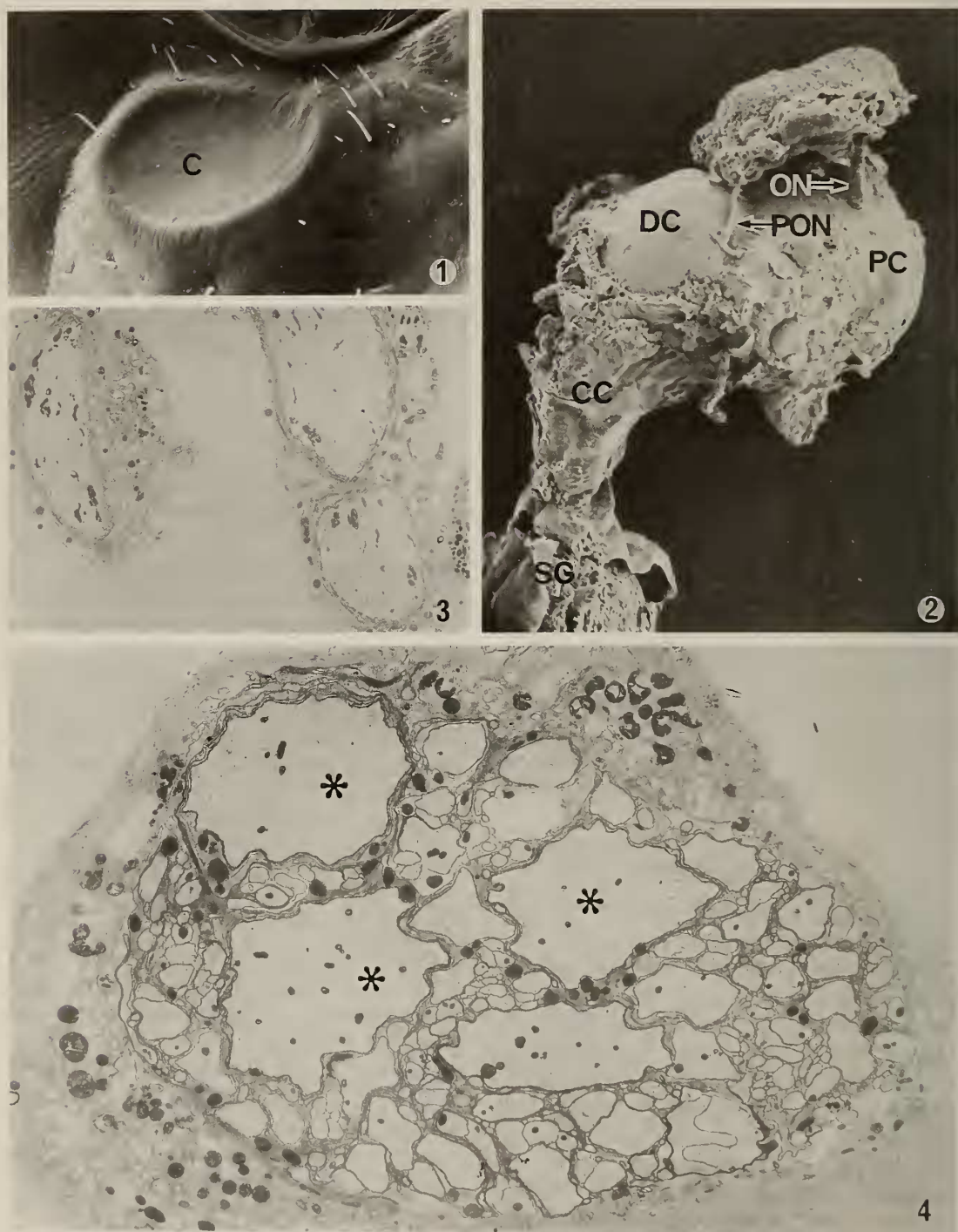


FIG. 1. A surface view of the ocellar region. Chaetic hairs occur around the ocellus. C, ocellus. $\times 68$.

FIG. 2. A bivalved brain viewed from the median plane. The para-ocellar nerve (PON) enters the deutocerebrum (DC). CC, circumoesophageal connective; ON, ocellar nerve; PC, protocerebrum; SG, suboesophageal ganglion. $\times 65$

with bees wax, and the para-ocellar nerve was exposed by partial removal of the cuticular integument. A suction electrode filled with physiological saline [9] was attached to the mid-region of the para-ocellar nerve, an indifferent electrode being inserted into the apex of the head. Two different stimuli were presented. Light from a tungsten lamp was focused upon the ocellus, its intensity being high enough to produce maximal ocellar ERG. Air puffs derived from an air compressor were directed towards the ocellar cornea through silicon tubes (2mm in diameter). The outlet of the tube was 10 mm apart from the head, and the velocity of the air stream was about 4 m/sec. Responses of the para-ocellar nerve were AC-amplified and photographed. Moreover, responses of chaetic sensilla located around the ocellar cornea to air puffs were extracellularly recorded by a sharpened tungsten electrode inserted into the base of the sensillum.

RESULTS AND DISCUSSION

The cockroach *P. americana* possesses a pair of ocelli: each ocellus ($400 \times 500 \mu\text{m}$) is located near the base of the antenna. The ocellar cornea is externally depressed, and sensory hairs occur around and on the cornea (Fig. 1). The ocellus is connected to the brain by two nerves. The ocellar nerve ($50 \mu\text{m}$ in thickness, $500 \mu\text{m}$ in length) originates in the posterior part of the ocellus, and enters the protocerebrum, whereas the para-ocellar nerve ($25 \mu\text{m}$ in thickness, $250 \mu\text{m}$ in length) originates in the anterior part of the ocellus and enters the deutocerebrum (Fig. 2). The para-ocellar nerve, viewed in cross sections through the mid-region, contains 130–200 fibers, about ten of them ranging between $1\text{--}5 \mu\text{m}$ (Fig. 4). The fibers contain many microtubules and mitochondria and only few vesicles. Adjacent fibers are separated from each other by thin glial cell envelopes, but no synaptic specializations occur among them. The para-ocellar nerve appears to be divided distally

into several bundles near the ocellus (Fig. 3).

The distribution of the para-ocellar nerve fibers within the CNS can be seen with cobalt backfills from the ocellus. The cobalt backfills show quite different courses of the ocellar nerve fibers and para-ocellar nerve fibers in the brain (Fig. 5). Usually several para-ocellar nerve fibers were stained. They descend through the ipsilateral circumoesophageal connective, and terminate in the suboesophageal ganglion. On their descending way they project lateral branches (up to $50\text{--}80 \mu\text{m}$ in length) in the mid-region of the circumoesophageal connective and into the anterior part of the suboesophageal ganglion (Fig. 6). They change their course in the suboesophageal ganglion towards the median plane, and terminate there with many branches (Fig. 7). Unlike the data obtained by silver impregnation [7], fibers, which were arborized and terminated around the olfactory lobe could not be cobalt-backfilled in the present study.

The distribution of the para-ocellar nerve fibers in the CNS, as was shown in the present study, is similar to previously reported mechanoreceptor axons: some examples are antennal mechanoreceptors of the locust which also terminate in the suboesophageal ganglion [10, 11]. In accordance with these anatomical findings it is assumed that the para-ocellar nerve may consist of primary axons of mechanoreceptive sensilla around the ocellar cornea: these axons must be backfilled by cobalt chloride which diffused out from the ocellus to the surrounding region. This assumption was physiologically confirmed. We found that the sensilla surrounding the ocellus responded to air puffs, and spike discharges were also recorded from the para-ocellar nerve in response to air puffs directed towards to ocellar cornea (Fig. 8).

These data suggest that the para-ocellar nerve contains axons transmitting mechanosensory information to the CNS. Whether the para-ocellar nerve is also involved in transmitting ocellar information remains unresolved, since we could

FIG. 3. Bundles of axons near the ocellar capsule. These bundles come together on their way to the brain to form the para-ocellar nerve shown in Fig. 4. $\times 2,200$.

FIG. 4. A cross section of the para-ocellar nerve near the deutocerebrum. Of about 200 fibers included three (asterisks) are more than $5 \mu\text{m}$ thick. $\times 5,200$.

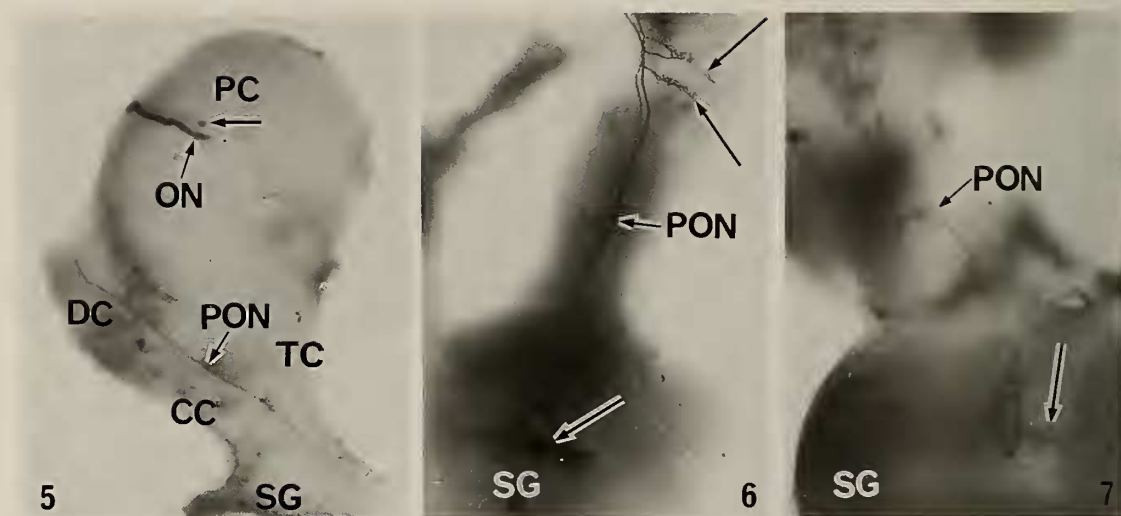


FIG. 5. Cobalt backfilled para-ocular nerve fibers (PON) and ocellar nerve fibers (ON) in a lateral view of the bivalved brain. Arrow, a cell body of the ocellar nerve fiber; CC, circumoesophageal connective; DC, duetocerebrum; PC, protocerebrum; TC, tritocerebrum; SG, suboesophageal ganglion. $\times 30$.

FIGS. 6 and 7. Cobalt backfilled para-ocular nerve fibers (PON) in frontal view of the brain. Note side branches (arrows) in Fig. 6, and terminal arborizations (arrow) in Fig. 7. CC, circumoesophageal connective; SG, suboesophageal ganglion. $\times 75$ in Fig. 6; $\times 94$ in Fig. 7.

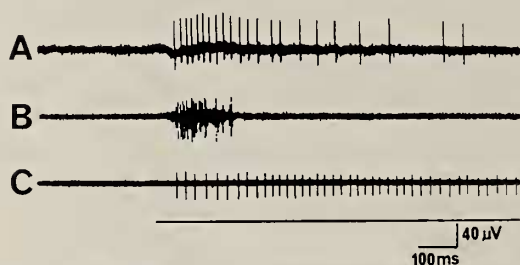


FIG. 8. Responses of the chaetic sensillum (A) and para-ocular nerve fibers (B, C) to air puffs to the ocellar cornea. The response of the para-ocular nerve fibers is phasic (B) or tonic (C). Multiple units were usually recorded (B). Bottom bar indicates the stimulus duration.

not find any responses to ocellar illumination. More elaborate studies are required to answer this question, because only several, probably thick, fibers were stained and their activities were recorded in the present study, and morphology and physiology of remaining fibers are still problematic.

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